Development of a Vertically-Profiling, High Resolution, Digital Zooplankton Imaging System

1. Abstract

Oceanographic survey systems that utilize optics to measure the abundance of small planktonic animals (zooplankton) are relatively new and few in number. They generally utilize NTSC video which has relatively low resolution. The objective of this project is to develop a new oceanographic, profiling instrument capable of measuring the abundance, taxonomic identity and size distributions of zooplankton and other small marine particles along with environmental data (temperature, salinity, pressure, fluorescence, optical transmittance) in the upper 250 m of the water column on centimeter vertical scales. Our system called ZOOVIS (Zooplankton Visualization and Imaging System) is a vertically profiling instrument designed to collect high resolution digital images of plankton sized particles in the 0-250 m depth range at sampling rates of up to 4Hz, along with environmental data at comparable spatial and temporal scales. The majority of system components have been acquired with acquisition of the remaining hardware projected for the summer of 1999. System assembly, desktop testing and subsequent packaging into underwater housings for tank testing is anticipated over the summer and fall of 1999. Tank testing will be designed to evaluate the image quality, resolution, and measurement precision of the system along with maximum sampling rates and suitability of the computer interface.

2. Interim Project Report

A. Objectives Accomplished to Date

1. **Design Completed** Our original design employed a passive backplane PC underwater to handle the command and control of the camera and image acquisition. From their we planned to send images to the surface over a fast fiber-optic (FO) network to a surface computer. That was necessary because at the time the proposal was written, we could not locate digital cameras on the market with a fiber-optic interface. Existing cameras all had short RS422 cables and so we planned to run data via RS422 to the underwater PC and transmit it up to the surface PC via a LAN. We subsequently identified a new digital camera manufactured by PixelVision Inc. that was compatible with a fast fiber-optic PCI interface. That camera utilized the same Thompson CCD that as the SMD4M4 camera that was quoted in the proposal. In our current design (Fig. 1) the underwater PC has been replaced by an FO multiplexor and FO modems.

   The hardware associated with ZOOVIS consists of the following:

   Camera Can This canister will be equipped with a clear port and will house the megapixel digital camera equipped with a very fast (f2.8) 28-105 mm Tamron Zoom lens coupled. Data from the camera will be converted from multimode to single mode fiber and multiplexed for transmission to the surface. Control commands from the surface PC will be converted to single mode fiber at the surface and multiplexed with the incoming camera data stream for bi-directional transmission along one of the cable fibers. This canister will also house the fiber optic modem and multiplexor for the CTD data.

Power Supply Can 110 V AC power will be transmitted along the three copper conductors in the cable to the power supply canister. This will house the digital camera power supply as well as a 24 V DC power supply for the strobe and 6 V power supplies for the fiber-optic multiplexors. By placing all the power distribution hardware within one case, we will reduce electrical noise that might interfere with camera image quality.

Strobe Can A linear arc strobe with a pulse length of 20 µs or less and a strobe rate of up to 4 Hz will be housed in a pressure canister with a clear end port. This strobe will produce a structured light sheet with a thickness of 2 cm and a width of at least 8 cm. The electronics for the strobe will be opto-isolated to prevent contamination of the camera data with noise.

CTD The CTD will operate from battery power although we have a provision to convert it to DC power in the future if required. Environmental data from, and control commands to an SBE19 Sea-Cat CTD (temperature, conductivity, pressure, fluorescence and optical transmittance) will be converted to a fiber optic signal with a fiber optic modem and passed bi-directionally along one of the electro-optical cable fibers using fiber optic multiplexors.

Electro-optical Cable The underwater canisters will be connected to the surface via a 300 m length of custom electro-optical cable consisting of three single mode optical fibers and three shielded copper conductors. The optical fibers are capable of carrying both 1310 and 1550 nm wavelengths. Camera control and data will flow bi-directionally along one fiber while CTD control and data will flow bi-directionally along a second fiber leaving the third fiber as a spare. 110 VAC power will be delivered via the three copper conductors (hot, neutral and ground). The waterproof cable has a diameter of 0.55 in, a breaking strength of 4800 lbs, and a minimum bend radius of 8 in.

Oceanographic Winch Our winch has been manufactured by SeaMac (Model 210EHLW) and consists of a 10 HP 230/460VAC motor driving a hydraulic pump. The winch is equipped with a level-wind and the drum has capacity for 300 m of 0.5 in cable with 2 in of clear flange. The bare drum rating is 1,200 lbs line pull with a variable line speed of 0-1 m s^{-1}. A fiber optic/conductive slip ring assembly (Focal Technologies) allows the passage of power and signal across the from the deck to the winch. Data on line-speed and tension are provided via RS232 standard.

Surface PC A 500 MHz Pentium II PC equipped with 128 MB RAM will be used to control the underwater systems and the winch. Camera data will arrive via a proprietary Linx2Fiber PCI card that is provided with the digital camera. CTD and winch data and control pass via an RS232 interface.

2. **Major Components Acquired/Ordered** The following key components of the system have been ordered or acquired as indicated in Table I.

Table I. Current status of major components of ZOOVIS

Equipment	Vendor	Status
Digital Camera BioXight BV20CCE with Lynx PCI Serial Fiber-Optic Interface	PixelVision Inc. Beverton OR	Delivery expected in late-June 1999, Demo Model at LSU
Linear-Arc Strobe producing a collimated light sheet in pressurized housing	SeaScan Inc., Falmouth MA	Currently under construction. Delivery expected late-July 1999
SeaCat SBE19 CTD with fluorometer and transmissometer	Sea-Bird Electronics,	Acquired
Electro-Optical Oceanographic Cable	Falmat Cable, San Marcos CA	Acquired
Oceanographic Winch	SeaMac Inc. Houston TX	Currently under construction. Delivery expected late-June 1999
Electro-Optical Slip Rings	Focal Technologies Inc. Sidney, NS	Currently under construction. Delivery expected late-June 1999
Acoustic Transponder		Out on bid
Fiber-optic multiplexor/modems	NBase/Xyplex Inc.	Ordered. Delivery late-May 1999
28-105 mm F-mount f2.8 Lens	Tamron	Acquired
Power Supply System	Various	Camera power acquired. Remaining components being built at LSU
Pressure Housings		Will be ordered once camera and FO hardware tested in lab.

3. **Laboratory Testing of Camera-Computer Interface Underway** After soliciting bids for the digital camera and FO interface, we selected the PixelVision BioXight system. Delivery of that system was delayed for two months due to limited manufacturing capacity. In April 1999 we were advised that one of the electronic components of the camera required a redesign and that delivery of the final production camera would not be possible until June 1999. In the interim we obtained a lower resolution (1024 x 1024 pixel) camera, the PCI FO interface and an example of the final production power supply (for the 2048x2048 pixel camera). That interim camera has been interfaced with an NT workstation and we are evaluating data transfer rates and camera command and control. The CTD will be interfaced with the control computer over the next month and we plan to have the system up and running for evaluation on the lab bench with the arrival of the strobe at the end of July. By that time, we will have acquired the underwater housings and the system will be packaged for tank testing. We envisage a system configured similarly to the instrument in Fig. 2.

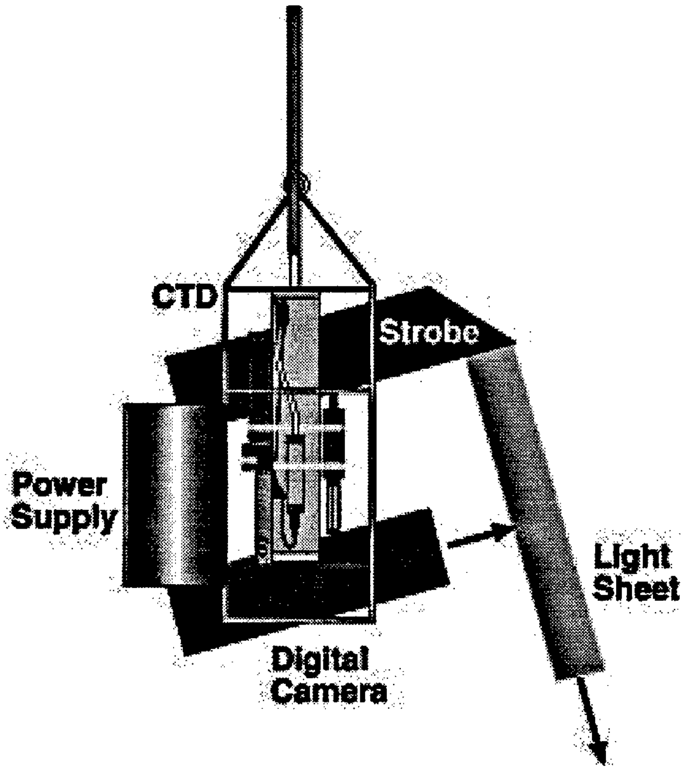

Figure 2. Schematic diagram of the underwater component of ZOOVIS. The system utilizes a PixelVision BioXight 2048 x 2048 pixel, 12 bit camera system. Illumination will be provided by a custom built (SeaScan Inc), 2 cm thick collimated light sheet. A Sea-Bird SBE19 SeaCat profiler equipped with a transmissometer and fluorometer provides environmental data.

4. **Winch, Electro-Optic Cable and Slip-Ring Assembly Under Construction** We have taken delivery of the electro-optical cable. The winch is undergoing final testing prior to delivery which is anticipated by the end of June. The electro-optical slip ring assembly is also expected by the end of June and that will be installed here at LSU when the cable is spooled on the winch.

B. Objectives to be Accomplished During Next Period

- **Complete desktop assembly and testing.** Once all components have been interfaced, the system will be packaged into underwater housings.
- **Tank Testing** The system will be connected to the winch and we will utilize a shallow tank to test the system. Our objectives will be to (1) identify and eliminate any ground faults; (2) optimize the orientation of the light sheet and camera; (3) measure the system resolution and precision by imaging microspheres of known diameters; (4) quantify the abundance of known densities of targets using microspheres and zooplankton cultures; and (5) evaluate, and if necessary, modify the computer interface between the camera and surface PC.
- **Field Testing** Begin to collect data from vessels of opportunity and at petroleum platforms. Mr. Sean Keenan will join our group as a graduate student and he will utilize ZOOVIS to quantify the zooplankton distributions around a petroleum platform for his M.S. thesis.

C. Unanticipated Problems

The major delay in this first year was associated with locating and evaluating a fiber-optic link between the camera and surface computer. We had originally decided to utilize an SMD4M4 camera after visiting Dr. Joe Katz at Johns Hopkins University and evaluating his digital camera holography system. Unfortunately, development of the fiber optic interface for the SMD camera was delayed and we had to look elsewhere for a suitable camera. We located PixelVision who manufacture a high resolution camera that uses the same CCD as the SMD4M4 and they had developed a high speed PCI fiber-optic interface to that camera. Our order was placed in the winter of 1998; however, as the delivery time approached, they notified us that their engineering group had identified a problem with the system hardware. This delayed the delivery of the camera and we are still waiting. PixelVision has assured us that we will receive our camera by late June.

Another delay was caused by the highly specialized nature of the system components. Since each component depends upon the specifications of the other components that it is linked to, we could not order all of the items at once. Only when we were certain that the camera system was not going to change, could be start to secure the various fiber optic modems, multiplexors and mode converters. Thus the delay in getting the camera, caused a cascade of delays in obtaining other system components.

Finally, the bureaucracy associated with the purchasing process at LSU (and imposed by State of Louisiana regulations), imposes additional, and completely unnecessary delays in acquisition of all items that must go out on competitive bids.

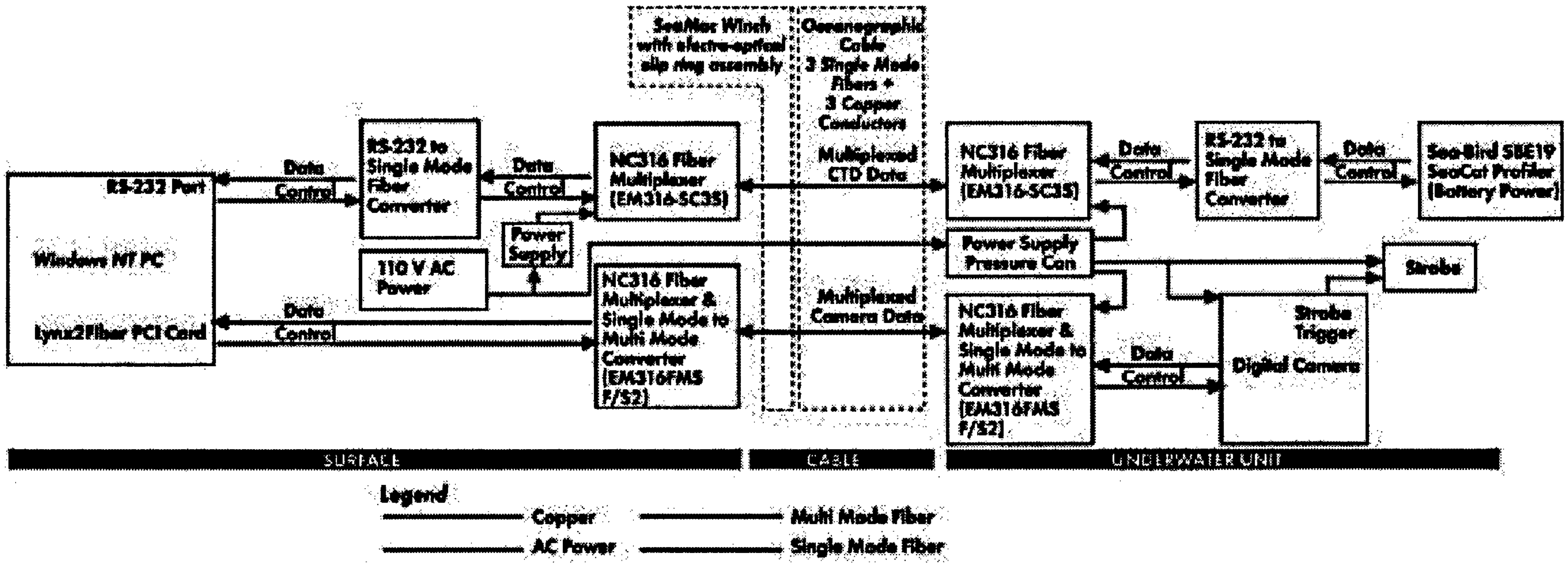

Figure 1. Schematic of the components and wiring organization of ZOOVIS.

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Benfield, Mark C.

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Coastal FIsheries Institute
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14. ABSTRACT

The objective of this project is to develop a new oceanographic profiling instrument capable of measuring the abundance, taxonomic identity and size distributions of zooplankton and other small marine particles along with environmental data (temp., salinity, pressure, fluorescence,optical transmittance) in the upper 250 m of the water column on centimeter verticle scales.

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